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SITE-SPECIFIC PHOSPHORUS MANAGEMENT WITH INORGANIC FERTILIZER AND MUNICIPAL SOLID WASTE COMPOSTAPPLICATION IN SALT AFFECTED SOIL

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Salt affected soils either developed from parent material (primary) or from anthropogenic activities (secondary) extended in arid and semi-arid regions reduced the crop growth. An increasing trend of salt affected soils is a major risk for food security and sustainable agriculture. The adverse effect of salt stress on crop growth is related with the specific ion toxicity, low osmotic potential and nutritional imbalance. Salt stress damages the soil physical properties that can be improved by addition of organic amendments such as municipal solid waste compost (MSWC). MSWC is eco-friendly, adds organic matter in soil and compensate the mineral fertilizer. Field experiments were conducted to assess the site-specific nutrient management using MSWC in rice-wheat cropping system under salt affected conditions. Application of inorganic and organic content (MSWC) keeping in consideration the P-fixation capacity of soils and site-specific nutrient management approach can improve the crop yields. Results revealed that site-specific use of mineral fertilizer with MSWC and integrated use of chemical fertilizers with MSWC in 80:20 ratio improve the paddy/grain yield and soil health. Site-specific and integrated use of chemical fertilizer with MSWC in 80:20 ratio produced the highest biomass / paddy and biomass/grain yield i.e. 11.04/2.67 and 5.62/2.70 Mg ha^{-1} at Kot Murad, District Hafizabad, respectively. Pre-sowing and postharvest soils analysis was carried out after transplanting/sowing of each crop. Integrated and site specific use of MSWC slightly reduced the salinity/sodicity than the initial status of soil while organic matter, available P, extractable K and Zn were increased compared to initial values.
Keywords: MSWC, site-specific P management, P-fixation factor, rice-wheat rotation

INTRODUCTION

Salt affected soils are distributed worldwide and considered a major threat to the semi-arid regions like Pakistan. Salt-affected soils are characterized by excessive soluble salts and dominance of Na^+ on exchange sites and main threat for sustainable agriculture causing reduction in yield of glycophytes (Hasegawa *et al.,* 2000; Qadir *et al.,* 2001; Sherani *et al*., 2017). The sodium (Na^+) and chloride (Cl^-) ions exerted osmotic stress and damaged the plants at cellular level (Mansour and Salama, 2000; Chinnusamy *et al.,* 2005). Salt-affected soils of Pakistan are mostly saline-sodic/sodic where Na^+ as dispersion agent hampers the hydraulic properties and obstruct the conducting pores. The management of salt affected soils can be carried out by addition of chemical amendments followed by leaching that replaced Na^+ from the exchange sites and biological means (Sharma and Minhas, 2005; Qadir *et al.,* 2007). Among the chemical amendments, gypsum is the most economical and reliable resource (Ghafoor *et al.,* 2011). Application of organic content to salt affected soils is an effective approach for improving chemical, physical and biological properties of soils although response is slow. Addition of organic amendments like green manures, farmyard, poultry manures, crop residues, press mud and MSWC improve the plant growth and soil quality (Hanay *et al.*, 2004; Sharma and Minhas, 2005; Tejada *et al.*, 2006; Qazi *et al.*, 2009; Wong *et al.*, 2009).
Imbalance and insufficient availability of nutrients is characterized feature of salt affected soils. Pakistani soils, especially soils affected by salinity/sodicity are generally deficient in nitrogen and phosphorus (Arain *et al.,* 2000). Soils have variable P fixation capacity depending upon many factors i.e. pH of the soil, organic matter, clay type and exchangeable cations. The P fixation capacity of soils have considerable relationship with pH, exchangeable cations, clay content, soluble phosphate, amount of P fixed and salinity/sodicity constrain its availability to plants. Phosphorus dynamics in the soil and its fixation/released characteristic have relevancy with the amount of P available for growing crops from the native soil pool (Dibb, 1990; Glendinning, 1990). Phosphorus fixation capacity of soils is responsible for its poor availability and limits the plant growth. It was reported that ~80% of added P fertilizers immobilized due to metal complexes (Schachtman *et al.,* 1998). The metal complexes formed due to phosphate anions with Ca or Mg in calcareous soils and Al or Fe in acidic soils promotes the P fixation. Phosphorus use efficiency can be enhanced and losses of P can be reduced by site-specific

application of P or on soil-need basis. Application of P on soil-need basis is the need of time for avoiding P losses and sustainable agriculture (McLean *et al.*, 1982; Juang *et al.*, 2002).

Salt-affected soils have disturbed soil structure and nutrient balance that can be improved by the application of organic matter. Organic matter improves the physical properties i.e. granulation, water holding capacity and chemical properties i.e. cation exchange capacity, adsorbing power of soils and promote the soil biology that is responsible for nutrient transformations and nutrients availability (Madejon *et al.*, 2001; Brady and Weil, 2005; Melero *et al.*, 2007). Organic amendment addition in salt affected soils promoted the hydraulic conductivity, water holding capacity and porosity of soil (Hussain *et al.*, 2001) and enhanced leaching, infiltration rate, water-holding capacity, aggregate stability and reduced electrical conductivity and ESP (Qadir *et al.*,2001). Applications of organic sources after bioconversion of organic substances i.e. FYM, poultry manure, press mud, crop residues, sewage sludge and municipal solid waste in the form of compost improve soil fertility and supplement the inorganic fertilizers (Madejon *et al.*, 2001; Melero *et al.*, 2007). Application of MSWC in the fields not only protects our environment by diminishing the waste dumps and incineration but also provides nutrients and aggregate stability to the crop stand (Yaghmaeian *et al.*, 2005; Alidadi *et al.*, 2008; Tzortzakis *et al.*, 2012). Addition of MSWC as an organic source promotes the leaching due to granulation and nutrient availability (Chun *et al.*, 2007; Munns and Tester, 2008; Rajendran *et al.*, 2009). Integrated nutrient management with MSWC in salt affected soils specifically for P application on soil need basis is better and more practical approach to acquire sustainability. Field studies at Kot Murad district Hafizabad were conducted to assess the approach of site-specific nutrient management using MSWC in rice-wheat cropping pattern under salt affected conditions.

MATERIALS AND METHODS

Site was selected at Kot Murad District Hafizabad and field was prepared. A permanent layout was designed for rice-wheat rotation lasting for three years. Studies were laid out in randomized complete block design (RCBD). Initial soil status of the selected site is given in Table 1. After determination of P fixation capacity of soil, the recommended standard test phosphorus (STP) target value of 16 mg kg^{-1} was maintained as described by McLean *et al.* (1982). The P fixation factor was determined and used as multiplier of differences to maintain the target sufficiency levels of P i.e. 16 mg kg^{-1}from mineral fertilizer and MSWC. The P fixation factor was calculated on the basis of P fixation capacity. The P fixation capacity was determined by taking 1.0 g soil, 0.5mL of KH_2PO_4 solution of 60 mg kg^{-1} P and equilibrated for 2 hours. The reciprocal of fraction of P recovered from added was designated as P fixation factor (F_p). The treatments are i) T_1- Control, ii) T_2- Recommended sole use of chemical fertilizer, iii) T_3- Site specific use of chemical fertilizer, iv) T_4- Integrated use of chemical fertilizer with MSWC in 80:20 ratio, v) T_5- Site specific integrated use of the chemical fertilizer and MSWC in 80:20 ratio. Recommended fertilizers applied to rice and wheat were 110-90-75 and 130-110-90 kg ha^{-1}, respectively. MSWC was analyzed and the composition along with the permissible limits is given in Table 2. Analysis of MSWC used in these studies has total N: 0.47-0.63%, total P: 0.33-0.38%, total K: 1.02-1.15%, Zn: 320-520, Cu: 86-109, Cd: 0-2.80, Co: 3.80-12.50 and Pb: 120-462 mg kg^{-1} (Tandon, 2005).

Table 1. Initial soil status at Kot Murad.

Parameters	Units	Soil Depth (0-15 cm)	Soil Depth (15-30 cm)
Soil Texture		Sandy Loam	Sandy Loam
Bulk density	(Mg m^{-3})	1.60(10-15cm)	1.58(20-25cm)
pH_s		8.74	8.67
EC_e	(dS m^{-1})	5.75	4.94
SAR	(mmol L^{-1})$^{1/2}$	38.67	29.47
Organic Matter	(%)	0.40	0.34
Available P	(mg kg^{-1})	8.60	7.85
Extractable K	(mg kg^{-1})	117.33	100.42
DTPA Extractable			
Zn	(mg kg^{-1})	0.80	0.48
Cu	(mg kg^{-1})	0.40	0.36
Co	(mg kg^{-1})	0.20	0.14
Cd	(mg kg^{-1})	0.20	0.18
Pb	(mg kg^{-1})	0.60	0.28

Table 2. Chemical composition of municipal solid waste compost.

Determinations	Units	Value	Permissible limits
Total N	%	0.47-0.63	-
Total P	%	0.33-0.38	-
Total K	%	1.02-1.15	-
Total Zn	mg kg^{-1}	320-520	7500
Total Cu	mg kg^{-1}	86-109	4300
Total Cd	mg kg^{-1}	0-2.80	85
Total Co	mg kg^{-1}	3.80-12.50	-
Total Pb	mg kg^{-1}	120-462	840

*Standards for sewage sludge and domestic septage established by US Environmental Protection Agency (EPA) in 1995.

Yield parameters of rice and wheat like biomass and paddy yield / grain yield data were recorded at harvest. Pre-sowing and post-harvest soil samples were collected from 0-15 and 15-30 cm soil depths. Different parameters (pH_s, EC_e, SAR, O.M and extractable K) were determined according to the methods described in US Salinity Lab. Staff (1954) and Tandon (2005). Soil bulk density was determined using core sampler from 10-15 and 20-25 cm soil depths (Blake and

Hartge, 1986) and soil texture was determined using hydrometer method (Bouyoucos, 1962) and available P was determined by modified Olsen method (Watanab and Olsen, 1965).DTPA extractable (Zn, Cu, Co, Cd and Pb) were determined using the methods as described by Lindsay and Norvell (1978). Data were subjected to statistical analysis using standard procedures following RCBD (Steel *et al.*, 1997). The differences among the means were compared by applying the Duncan's multiple range tests (Duncan, 1955).

RESULTS AND DISCUSSION

Three years experimentations were carried out with permanent layout in rice-wheat cropping system at Kot Murad district Hafizabad. Before start of the experiments, initial soil status showed that soil was sandy loam, bulk density: 1.60 and 1.58 Mg m^{-3} in 10-15 cm and 20-25 cm soil depth, respectively (Table 1). Soil analysis showed that soil was sandy loam, saline sodic with moderate available P status and low in organic matter content.

Data regarding biomass and paddy/grain yield of rice and wheat are presented in Table 3. The results revealed that site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio produced significantly higher biomass and paddy yield (11.04 and 2.67 Mg ha^{-1}) followed by integrated use of chemical fertilizers with MSWC in 80:20 ratio) i.e. 10.02 and 2.48 Mg ha^{-1}, respectively. Site specific use of chemical fertilizers produced higher biomass and paddy yield (9.46 and 2.30 Mg ha^{-1}) than recommended sole use of chemical fertilizers (9.00 and 2.19 Mg ha^{-1}) and lowest with control (3.89 and 0.96 Mg ha^{-1}).

Site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio produced highest biomass and grain yield of wheat as well i.e. 5.62 and 2.70 Mg ha^{-1} followed by integrated use of chemical fertilizers with MSWC in 80:20 ratio i.e. 5.12 and 2.61 Mg ha^{-1}, respectively. Site specific use of chemical fertilizers produced higher biomass and grain yield i.e. 5.32 and 2.55 than recommended sole use of chemical fertilizers i.e. 5.06 and 2.41 compared to control i.e. 1.91 and 0.92 Mg ha^{-1}, respectively (Table 3).

Table 3. Effect of integrated application of P on biomass and paddy / grain yield of rice and wheat at Kot Murad.

Average of three years)

Treatments	Rice Yield (Mg ha^{-1})		Wheat Yield (Mg ha^{-1})	
	Biomass	Paddy	Biomass	Grain
T_1- Control	3.89* E	0.96 E	1.91 C	0.92 D
T_2- Recommended sole use of chemical fertilizers	9.00 D	2.19 D	5.06 B	2.41 C
T_3-Site specific use of chemical fertilizers	9.46 C	2.30 C	5.32 AB	2.55 B
T_4- Integrated use of chemical fertilizers with MSWC in 80:20 ratio	10.02 B	2.48 B	5.12 AB	2.61 AB
T_5-Site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio	11.04 A	2.67 A	5.62 A	2.70 A
LSD	0.361	0.087	0.565	0.124

*Means sharing the same letter(s) in a column do not differ significantly at p<0.05 according to Duncan's Multiple Range Test.

Table 4. Soil analysis after rice harvest (0-15 and 15-30cm) at Kot Murad.

Average of three years)

Treatments	pH_s	EC_e (dS m^{-1})	SAR (mmol $L^{-1})^{1/2}$	O.M. (%)	Available P (mg kg^{-1})	Extractable K (mg kg^{-1})
			(0-15 cm)			
T_1	8.533 A	4.13 B	24.36 A	0.277 B	5.11 B	87.26 B
T_2	8.517 B	3.23 B	22.49 B	0.537 A	13.15 A	144.83 A
T_3	8.523 AB	3.22 B	22.48 B	0.550 A	12.22 A	144.10 A
T_4	8.500 C	3.19 B	21.81 B	0.620 A	13.27 A	148.81 A
T_5	8.500 C	3.15 B	21.71 B	0.610 A	12.73 A	148.25 A
LSD	0.015	0.194	1.426	0.132	4.125	23.576
			(15-30 cm)			
T_1	8.57 A	4.24 A	27.17 A	0.217 B	4.72 B	83.41 B
T_2	8.55 BC	3.73 B	24.26 B	0.407 A	8.76 A	109.42 A
T_3	8.56 AB	3.69 B	23.59 B	0.413 A	8.73 A	109.81 A
T_4	8.54 CD	3.69 B	23.60 B	0.447 A	9.04 A	111.31 A
T_5	8.53 D	3.62 B	24.09 B	0.437 A	8.99 A	111.22 A
LSD	0.014	0.319	2.488	0.093	2.828	17.39

*Means sharing the same letter(s) in a column do not differ significantly at p<0.05 according to Duncan's Multiple Range Test.

Table 5. Soil analysis after wheat harvest (0-15 and 15-30cm) at Kot Murad.

(Average of three years)

Treatments	**pH_s**	**EC_e ($dS\ m^{-1}$)**	**SAR ($(mmol\ L^{-1})^{1/2}$)**	**O.M. (%)**	**Available P ($mg\ kg^{-1}$)**	**Extractable K ($mg\ kg^{-1}$)**
			(0-15 cm)			
T_1	8.516	3.983 A	22.62	0.243 B	4.13 B	81.87 B
T_2	8.497	3.163 B	21.18	0.567 A	13.98 A	151.68 A
T_3	8.520	3.177 B	21.90	0.573 A	12.67 A	150.48 A
T_4	8.507	3.147 B	21.38	0.657 A	14.29 A	152.16 A
T_5	8.507	3.143 B	21.35	0.633 A	13.13 A	152.52 A
LSD	0.024	0.081	8.654	0.124	3.756	18.52
			(15-30 cm)			
T_1	8.53 A	4.10 A	23.46 A	0.183 B	3.75 B	79.07 B
T_2	8.51 B	3.36 B	21.97 B	0.427 A	8.93 A	113.04 A
T_3	8.53 A	3.34 B	22.55 AB	0.430 A	8.86 A	113.30 A
T_4	8.52 AB	3.31 B	21.88 B	0.467 A	9.24 A	114.62 A
T_5	8.52 AB	3.32 B	21.95 B	0.443 A	9.13 A	113.65 A
LSD	0.018	0.075	1.005	0.086	2.104	14.83

*Means sharing the same letter(s) in a column do not differ significantly at $p<0.05$ according to Duncan's Multiple Range Test.

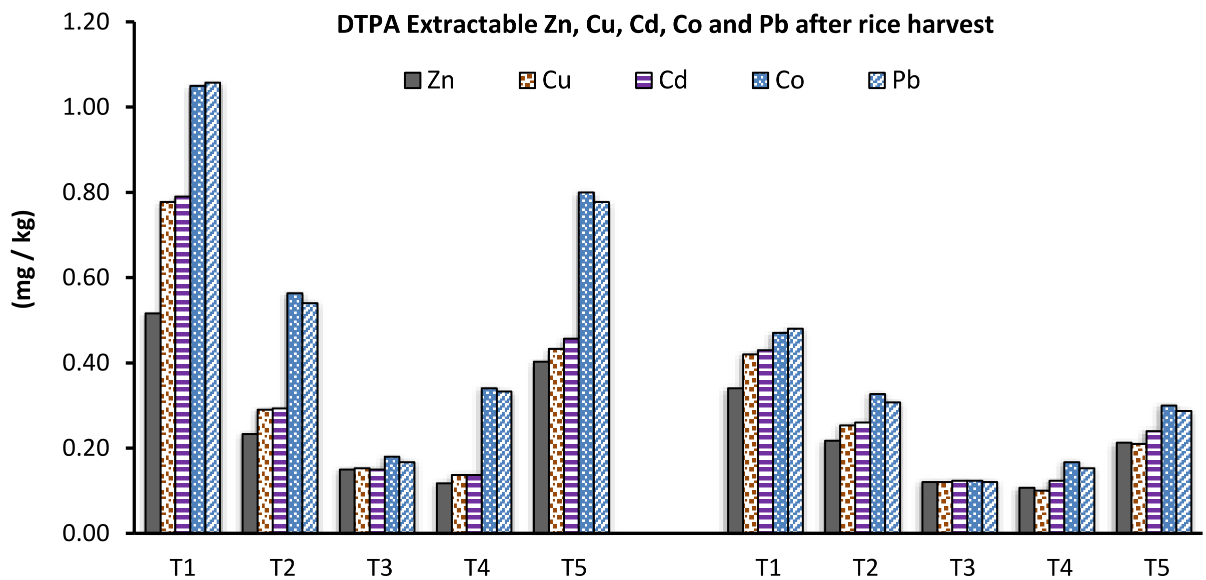

Figure 1. Soil analysis's after rice harvest at Kot Murad for DTPA Extractable (Zn, Cu, Cd. Co, Pb) at 0-15 cm and 15-30 cm. T_1- Control, T_2- Recommended sole use of chemical fertilizers, T_3-Site specific use of chemical fertilizers, T_4- Integrated use of chemical fertilizers with MSWC in 80:20 ratio, T_5-Site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio.LSD for DTPA Extractable Zn, Cu, Cd. Co, Pb for 0-15cm: 0.194, 0.130, 0.042, 0.089, 0.167.LSD for DTPA Extractable Zn, Cu, Cd. Co, Pb for 15-30 cm: 0.074, 0.078, 0.022, 0.019, 0.049

The results regarding post-harvest soil analysis of rice and wheat (Table 4, 5 and Fig. 1, 2) clearly demonstrated that salinity/sodicity of the soil were decreased initial values and decrease was higher in upper soil depth (0-15 cm). Slight improvement in organic matter, available P, extractable K contents was observed. Maximum improvement in organic matter, available P, extractable K contents was observed in integrated use of chemical fertilizers with MSWC in 80:20 ratio i.e. 0.620%, 13.27and 148.81 mg kg^{-1} and with site specific integrated use of chemical fertilizer with MSWC in i.e. 0.610%, 12.73and 148.25 mg kg^{-1}.

Application of MSWC accumulated Zn, Cu, Cd, Co and Pb especially in integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_4) and site specific integrated use of chemical fertilizer with MSWC in (T_5) than the rest of treatments. Improvement in organic matter, available P and

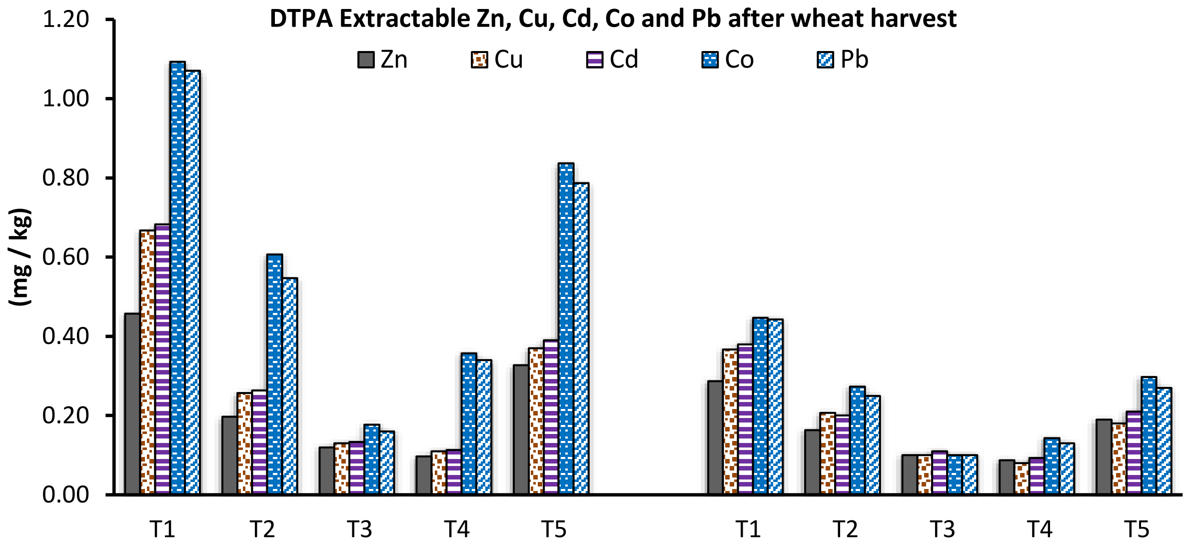

Figure 2. Soil analysis after wheat harvest at Kot Murad for DTPA Extractable (Zn, Cu, Cd. Co, Pb) at 0-15 cm and 15-30 cm. T_1- Control, T_2- Recommended sole use of chemical fertilizers, T_3-Site specific use of chemical fertilizers, T_4- Integrated use of chemical fertilizers with MSWC in 80:20 ratio, T_5-Site specific integrated use of chemical fertilizer with MSWC in 80:20 ratio.LSD for DTPA Extractable Zn, Cu, Cd. Co, Pb for 0-15cm: 0.165, 0.1026, 0.0492, 0.075, 0.114.LSD for DTPA Extractable Zn, Cu, Cd. Co, Pb for 15-30 cm: 0.074, 0.045, 0.011, 0.023, 0.019

extractable K was more in upper soil depth than lower soil depth especially in integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_4) and site specific integrated use of chemical fertilizer with MSWC in (T_5) (Hussain *et al.*, 2001; Qazi *et al.*, 2009).

After rice harvest, increase in organic matter content was observed i.e. 0.277% to 0.620% with T_4 and 0.610 with T_5. Increase in available P and extractable K was observed compared to control and highest increase was observed i.e. 13.27 and 148.81 mg kg^{-1} with T_4 and 12.73 and 148.25 with T_5 compared to control i.e. 5.11 and 87.26 mg kg^{-1}, respectively. After rice harvest, the highest decrease in $EC_e$and SAR was observed in upper soil depth with site-specific integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_5) where values of EC and SAR were recorded as 3.15 and 21.71 (dS m^{-1} and 24.36 (mmol L^{-1})$^{1/2}$, respectively. Integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_4) revealed these parameters as 3.19 and 21.81 (dS m^{-1} and 24.36 (mmol L^{-1})$^{1/2}$ as compared to control i.e. 4.13 and 24.36 (dS m^{-1} and 24.36 (mmol L^{-1})$^{1/2}$, respectively.

After wheat harvest, increase in organic matter content was observed from 0.243 to 0.657% with integrated use of chemical fertilizers with MSWC in 80:20 ratio and 0.633 with site specific integrated use of chemical fertilizer with MSWC. Increase in available P and extractable K was observed compared to control and highest increase was observed i.e. 14.29 and 152.16 mg kg^{-1} with T_4 and 13.13 and 152.52 with T_5 compared to control i.e. 4.13 and 81.87 mg kg^{-1}, respectively. After wheat harvest, the EC_e and SAR were decreased and highest decrease in EC_e and SAR was observed in upper soil depth with site-specific integrated use of chemical fertilizers with MSWC in 80:20 ratio i.e. 3.143 dS m^{-1} and 21.35 (mmol L^{-1})$^{1/2}$. Similar was the effect of integrated use of chemical fertilizers with MSWC in 80:20 ratio (T_4) i.e. 3.147 and 21.38 as compared to control i.e. 3.983 (dS m^{-1}) and 22.62 (mmol L^{-1})$^{1/2}$, respectively.

The growing of rice in flooded conditions might be due to the fact that soluble salts were leached down by improvement in infiltration rate and hydraulic conductivity resulting in decrease in soil EC_e and SAR. Addition of organic content such as MSWC improved the granulation and aggregate stability might be the reason of reduction in EC_e and SAR (Hussain *et al.*, 2001; Qadir *et al.*, 2001). Improvement in organic matter of soil with MSWC application was also in accordance with the findings of Hussain *et al.* (2001) and Qazi *et al.* (2009).

Application of organic content to salt affected soil improved the granulation, aggregate stability, soil health and promoted crop growth. Salt-affected soils characterized with disturbed soil structure and with low organic content enhanced the damage to crop growth (Blum *et al.*, 2004; Van-Camp *et al.*, 2004; Chitravadivu *et al.*, 2009; Laland Follett, 2009). Application of MSWC to agriculture fields not only protect the environment due to their incineration and provide an economical method of dumping wastes but also improved the organic matter in soils that act as binding force to the dispersed conditions (Parnaudeau *et al.*, 2004; Van-Camp *et* *al.,* 2004; Gigliotti *et al.,* 2005; Spargo *et al.,* 2006). Application of MSWC also adds / conserves nutrients in soil and thus compensates the mineral fertilizers, improves the soil physical conditions (Bellamy *et al.,* 1995; Tejada *et al.,* 2001; Zhang *et al.,* 2006; Weber *et al.,* 2007).

Application of MSWC promotes soil available P and extractable K as reported in results i.e. in treatments site-specific integrated use of chemical fertilizer with MSWC in 80:20 ratio and integrated use of chemical fertilizers with MSWC in 80:20 ratio. Improvement in available P and extractable K with site-specific application of nutrient and integrated use of chemical fertilizers with MSWC was verified from the findings of many researchers (Warman *et al.,*2004; Zhang *et al.,* 2006; Qazi *et al.,* 2009). Site-specific application of P than conventional use is considered better approach by saving P and avoiding the losses (McLean *et al.,* 1982; Glendinning, 1990; Juang *et al.,* 2002).

Application of MSWC to agriculture fields besides its benefits of environmental safety, adding organic matter in soil may also cause severe threat by adding huge amount of heavy metals in soil (Zhang *et al.,* 2006). Detailed soil analysis of fields and MSWC should be carried out to assess the extent of heavy metals for permissible limits of heavy metals (Weber *et al.,* 2007). Minor increase in DTPA extractable Zn, Cu, Co, Cd and Pb was observed in integrated use of chemical fertilizers with MSWC in 80:20 ratio and site specific integrated with MSWC in 80:20 ratio and other treatments.

DTPA extractable Zn, Cd, Cr, Pb and Ni were also enhanced with MSWC application (Qazi *et al.,* 2009). It was reported that Zn, Ni, Cd, Cr and Pb concentration was improved in soil with MSWC application (Hernando *et al.,* 1989; Pinamonthi *et al.,* 1999; Hargreaves *et al.,* 2008).

Conclusion: Studies concluded that MSWC application with mineral fertilizer and site-specific application of P is an economical approach and results in crop growth promotion. Site-specific use of chemical fertilizers with MSWC and integrated use of chemical fertilizers with MSWC in 80:20 ratio increased the paddy/grain yield and fertility status of the soil. However, there was a slight increase in the heavy metal concentrations in soil in the treatments where MSWC was applied.

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